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ATMOSPHERIC AND COSMIC INTERFERENCE WITH RADIO RECEPTION

M. P. Dolukhanov

/Comment: The following is the complete text of Chapter VIII, "Atmospheric and Cosmic Interference With Radio Reception," of the book Rasprostraneniye Radiovoln (Radio-Wave Propagation) by M. P. Dolukhanov.

Figures referred to are appended./

In considering various methods of calculating field intensity, it has repeatedly been observed that the reception conditions are determined by the ratio of the signal field intensity to the noise level rather than by the absolute value of field intensity. For this reason, it is of considerable practical importance to be able to determine the noise level. If we know the signal-to-noise ratio required for a certain form of communications, we can determine the necessary field intensity at the reception point and also other parameters of the radio communications line.

Disregarding sources of interference inherent in the receiving equipment, which are considered in detail in manuals on receiving equipment, we will limit ourselves to the discussion of external interferences, which include man-made interference, atmospheric interference, and cosmic interference. The last two are of interest here.

At present, it has been firmly established that the major source of atmospheric interference is actually thunderstorms. We distinguish the interference created by local thunderstorms from that owing its origin to a universal center of thunderstorm activity.

Oscillographic study of the form of current arising in thunderstorm discharges shows that this current has the form of an aperiodic or rapidly damped oscillatory discharge with a total duration from 0.1 to 3 milliseconds. Each

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such impulse creates a continuous spectrum of frequencies. If we let τ_0 be the mean duration of the pulse and $f_0 = 1/\tau_0$ the reciprocal of this duration, we can show that, for typical forms of atmospheric interference, the relative value of the sinusoidal component of the spectrum in the region of frequencies $f \gg f_0$ can be represented by the formula

$$A = A_0 \frac{f_0}{f} \qquad (1)$$

Where A represents the relative amplitude (spectral density) of the frequency component f.

Formula (1) shows that the relative amplitudes are largest in the frequency region $f \approx f_0$, i.e., in the interval from 300 to 10,000 cycles. In the radio wave band, the relative amplitude of the sinusoidal components is inversely proportional to the frequency, i.e., it should decrease with increasing frequency. When atmospheric interference is created by local thunderstorms, formula (1) gives the intensity of interference as a function of frequency.

When the interference is created by remote centers of thunderstorm activity, the general dependency of noise level on frequency will be determined not only by formula (1) but also by the propagation conditions for radio waves of a particular frequency along the path "center of thunderstorm activity - reception point." Under such conditions, each thunderstorm discharge should be regarded as a source of radio waves filling a continuous frequency spectrum which are propagated to the reception point in the same way as waves radiated by antennas of radio stations.

Observations made with direction-finding equipment on the direction of arrival of atmospheric interference show that the main centers of interference are in fact the regions of most intense thunderstorm activity, i.e., equatorial Africa, equatorial America, India, the Malay Archipelago, and others. The intensity of atmospheric interference gradually decreases as one moves away from these regions.

The world-wide geographical distribution of atmospheric interference is characterized by means of charts of atmospheric interference. A chart of atmospheric interference for the summer months is shown in Figure 1 and one for the winter months in Figure 2. Both charts were drawn up from measurements made before 1940.

The entire world is divided into five zones on these charts. The fifth zone corresponds to the regions of most intense atmospheric interference (these zones essentially correspond with the main centers of thunderstorm activity), while the first zone characterizes the region with the lowest level of atmospheric interference.

It is relatively easy to establish the dependency of interference on frequency at the reception point if one knows the dependency of interference field intensity on frequency at the point of origination and the dependency of absorption on frequency along the propagation path from the point of interference origination to the reception point. The basic regularities of propagation processes should appear in this dependency, i.e., we should expect that in long- and medium-wave bands, the interference level will be higher at night than in the daytime. Medium waves are absorbed considerably in the daytime and therefore the difference in the interference level between day and night should be particularly noticeable in this band.

In the short-wave band, high values of field intensity should be observed in the "night-wave" region (from 35 to 60 m) at nighttime, and conversely in the "day-wave" region (from 10 to 25 m) during the day.

The above is well illustrated by Figure 3, which was drawn up by generalizing and processing the results of interference-level measurements. Frequencies are plotted along the abscissa and relative values of interference field intensity during local storms and interference during day and night are plotted along the ordinate. The figure holds for medium latitudes.

Whereas the interference level from local storms decreases monotonically with frequency (the upper curve of Figure 3), the frequency distribution of interference at nighttime is characterized by a sharp drop in the high-frequency region (in the "day-wave" region), while the frequency distribution in the daytime shows a minimum at 2 Mc and a maximum around 15 Mc.

For waves shorter than 10 m, where the ionosphere no longer is effective in the propagation process, atmospheric interference is created only by local thunderstorms.

Because of the random nature of atmospheric interference, which is actually a series of pulses of diverse form and duration superposed on one another, the determination of the interference field intensity at the reception point is somewhat difficult. It must be precisely established exactly what is understood by the interference field intensity in each separate case.

Usually, the interference field intensity is understood to be the equivalent field intensity of an unattenuated signal which creates the same total effect as the interference at the output of a receiver with a definite passband. The interference field intensity must be related to the passband of the receiver because interference fills a continuous frequency spectrum and, as a result, the interference energy at the output of the receiver is proportional to the passband. By the same considerations, the effective value of interference voltage at the receiver output is proportional to the square root of the receiver passband.

In the ultrashort-wave band, the level of atmospheric interference drops off sharply. Recent observations have shown that the basic source of external interference at frequencies above 300 Mc is the radio radiation of the galaxy and the sun.

The sources of galactic radio radiation are located in definite sectors of the sky. The chief source of radio radiation is the region of Scorpio and Taurus, i.e., the center of the galaxy.

In this band, we must also reckon with interference created by radio radiation of the sun. This shows up as interference to radio reception when sharply directional receiving antennas are used, but only when these antennas are directed toward the sun. As with other sources of interference, the radio radiation of the sun is characterized by a sharply defined frequency dependency; in the ultrashort-wave band, the intensity of solar radio radiation drops off with increasing frequency. In the meter-wave band, the intensity of solar radio radiation increases sharply when a group of spots passes through the central meridian and in general varies sharply from day to day. Radiation in the meter-wave band is apparently connected with outbreaks of solar activity; the radio radiation of the sun is much more constant in the centimeter-wave band.

At the suggestion of Academician N. D. Papaleksi, it was decided that a solar eclipse should be used to study the problem of the nature of solar radio radiation. On 20 May 1947, an expedition of the Academy of Sciences USSR observed a complete eclipse on the shores of Brazil. Processing of the observational data showed that the upper layers of the solar atmosphere play a substantial role in solar radio radiation.

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Qualitative Evaluation of Interference Level. Determination of the Field Intensity Necessary for Reliable Signal Reception

Man-Made Interference

The level of man-made interference in the radio frequency band must be determined in each practical case by means of special noise-level meters. An idea of the mean level and the frequency distribution of man-made noise can be obtained from Table 1 below, which gives approximate values for the field intensity in $\mu v/m$ necessary for good radio-broadcasting reception. It is assumed that the signal field is approximately 10-30 times the interference level.

Table 1. Approximate Values of Field Intensity Necessary for Reception of Radio-Broadcast Programs

Wave Band (m)	Field Intensity (μ/m)		
	Large Cities	Small Cities	Rural
1,000-2,000	10,000	2,000	500
200-550	5,000	1,000	250
10-60	500	200	50

Atmospheric Interference

In making technical calculations, it is more convenient to operate, not with interference field intensities, but instead with the signal field intensity required for a certain form of communications because of the indefiniteness of the concept of atmospheric interference field intensity.

First, from the charts of world-wide distribution of atmospheric interference for summer and winter, one determines in which one of the five zones reception point is located. The territory of the Soviet Union covers the first three zones, i.e., it is located in relatively favorable conditions with respect to atmospheric interference. An increase of the interference level in the summer months because of local storms is characteristic of the Soviet Union.

Then the field intensity necessary for sufficiently good radiotelephone (not radio broadcasting) reception is determined from the graphs shown in Figures 4, 5, and 6 according to the location of the reception point for given values of frequency and time of day. The graphs apply to the central regions of the interference zones. They were obtained by generalizing a considerable amount of operational data, but nevertheless they give only approximate values of the field intensity required.

The following table of correction coefficients serves as a guide in determining the required field intensity at the reception point for other types of operation.

Table 2. Ratio of Field Intensity Required for Various Types of Operation to Field Intensity Required for Sufficiently Good Radiotelephone Reception

Type of Operation	Quality of Reception	
	Satisfactory	Good
Radiotelephone	0.15	1.00
Telegraph reception by ear	0.04	0.10

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Type of Operation	Quality of Reception	
	Satisfactory	Good
Reception on an undulator [paper-tape recorder]	0.15	0.40
Teletype reception	0.25	0.75
Radiobroadcast reception	0.27	2.00
Facsimile reception	0.15	0.40

Using this table, it is easy to convert the field intensities determined from Figures 4, 5, and 6 to the intensity required for the particular type of operation and necessary quality of reception.

Galactic Interference

Galactic interference appears in the wave band below 10 m, where atmospheric interference is almost absent and where the sensitivity of the receiving equipment is determined by the noise level in the active resistance of the antenna circuit. For qualitative evaluation of the level of galactic interference in these conditions, it is convenient to use the coefficient, which shows how many times the noise level created by the active antenna resistance increases under the action of galactic interference.

In the frequency band from 18 to 160 Mc, the dependency of the coefficient on frequency, averaged over the entire sky surface, is expressed fairly well by the formula:

$$\theta = 1.8 \times 10^6/f^3 \text{ (Mc)} \qquad (2)$$

Interference of Solar Origin

Solar radio radiation creates interference to radio reception only in the wave band below 10 m, and only when sharply directional antennas, oriented toward the sun, are used. In periods when groups of spots pass through the central meridian, the coefficient θ may reach a value of 20 for a 10-cm wave.

[Appended figures follow.]

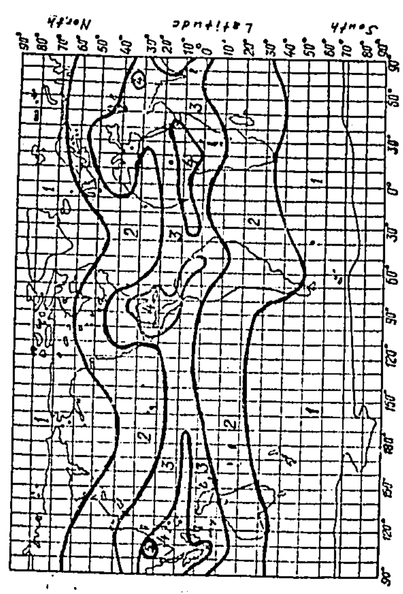

Figure 1. Chart of the Distribution of Atmospheric Interference for the May - September Period

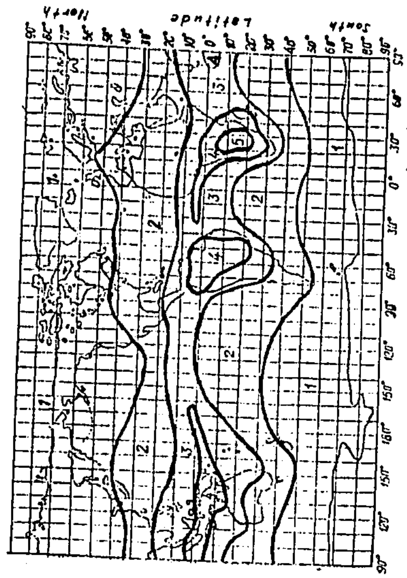

Figure 2. Chart of the Distribution of Atmospheric Interference for the November - March Period

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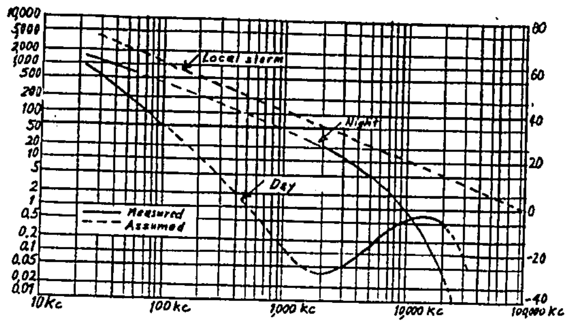

Figure 3. Relative Values of Interference Field Intensity During Local Storms and Interference Field Intensity at Night and in the Daytime

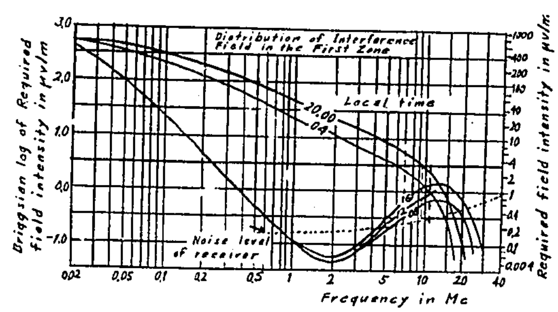

Figure 4. Dependency of Required Field Intensity on Frequency for Sufficiently Good Radiotelephone Reception in the First Interference Zone

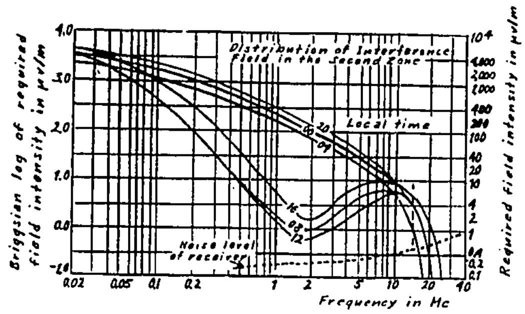

Figure 5. Dependency of Required Field Intensity on Frequency for Sufficiently Good Radiotelephone Reception in the Second Interference Zone

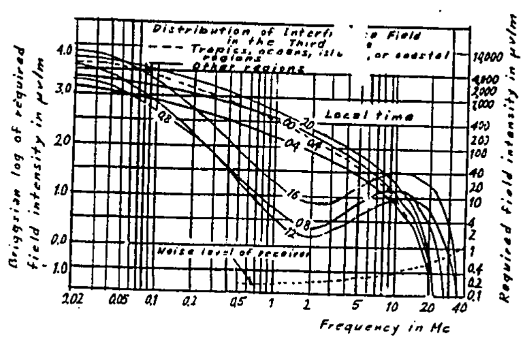

Figure 6. Dependency of Required Field Intensity on Frequency for Sufficiently Good Radiotelephone Reception in the Third Interference Zone

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